

SWITCH HITTING IN BASEBALL: APPARENT RULE-FOLLOWING, NOT MATCHING

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Many studies, including some dealing with shot selection in basketball and play selection in football, demonstrate that the generalized matching equation provides a good description of the allocation of time and effort to alternative responses as a function of the consequences of those alternatives. We examined whether it did so with respect to left- and right-handed at bats (alternative responses) and left- and right-handed total bases earned, runs batted in, and home runs (three consequences) for the outstanding baseball switch-hitters Mickey Mantle, Eddie Murray, and Pete Rose. With all hitters, undermatching, suggesting insensitivity to the consequences of behavior (reinforcement), was evident and there was substantial bias towards left-handed at bats. These players apparently chose handedness based on the rule “bat opposite the pitcher,” not on differential consequences obtained in major league games. The present findings are significant in representing a counter-instance of demonstrations of a matching relationship in sports in particular and in human behavior in general and in calling attention to the need for further study of the variables that affect choice.

Key words: matching equation, generalized matching equation, matching law, sports psychology, baseball, rule-governed behavior

Since the 1961 appearance of Herrnstein’s seminal article, research on the relation between environmental inputs (e.g., rates of reinforcement) and behavior outputs (e.g., rates of responding) under concurrent schedules as quantified in various matching equations has generated substantial interest, many data, and occasional controversy among behavior analysts (e.g., Davison & McCarthy, 1988; deVilliers, 1977; McDowell, 2005). An especially important algorithm is the generalized matching equation (McDowell, 2005). When expressed in logarithmic form, which is common (Davison & McCarthy, 1988), it takes the following form:

$$\log (B1/B2) = a \log (R1/R2) + \log c \quad (1)$$

where B1 is behavior (or time) allocated to alternative one, B2 is behavior (or time) allocated to alternative two, R1 is reinforcement received under alternative one, R2 is reinforcement received under alternative two, *a* is the slope of the regression line relating behavioral and reinforcement variables, and $\log c$ is the intercept of that line. In this formulation, the slope (*a*) is 1.0 when there is

strict matching, greater than 1.0 when there is overmatching, and less than 1.0 when there is undermatching. The intercept ($\log c$) is termed bias and when positive shows a bias toward B1 and when negative shows a bias toward B2.

Researchers have examined whether the generalized matching equation (or alternative equations) accurately describe relations between behavioral outputs and environmental inputs in nonhumans and in humans responding under a wide variety of conditions, including some of applied relevance (e.g., Borrero et al., 2007; Borrero & Vollmer, 2002; McDowell & Caron, 2010a; Neef, Shade, & Miller, 1994). Although a few attempts to apply matching analyses to the behavior of humans in their everyday environments are at best metaphorical, as Poling and Foster (1993) discuss, several studies have demonstrated matching outside laboratory settings (see McDowell & Caron, 2010b). For example, in the realm of sports psychology three studies show that the generalized matching equation provides a reasonable description of the relation between the relative number of two- and three-point shots taken by basketball players and the relative number of points yielded by those shots (Alferink, Critchfield, Hitt, & Higgins, 2009; Romanowich, Bourret & Vollmer, 2007; Vollmer & Bourret, 2000). Two other studies demonstrate that it does so with

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respect to play selection (runs versus passes) and yards yielded in professional football games (Reed, Critchfield, & Martens, 2006; Stilling & Critchfield, 2010). Although these studies clearly illustrate that choice in athletic endeavors can be influenced by relative payoff, their authors emphasize that such choices are complex and are likely to be influenced by several other variables, including distal histories of reinforcement and current derived relations (i.e., rules).

Given that this is the case, exploring whether the generalized matching equation accurately describes other sporting choices is of interest. The present exploratory study did so by examining the relation between right- and left-handed at bats by three former major-league switch-hitters, Mickey Mantle, Pete Rose, and Eddie Murray, and three consequences of those types of at bats: total bases earned (TB), runs batted in (RBI), and home runs (HR). Each player was a successful switch-hitter who played regularly for over 15 years in major league baseball. Switch-hitters, who are rare in the major leagues, bat both right- and left-handed. The purpose of the study was to examine further the range of everyday situations under which matching is obtained.

METHOD

For each player and each season that he played, data were obtained from Baseball-Reference.Com (2010), which provides separate information for left- and right-handed at bats. Data were available for 17 (1952–1968), 21 (1977–1997) and 24 (1963–1986) years for Mantle, Murray, and Rose, respectively. The data source did not provide information for Mantle's first year in the major leagues and indicated that 1–2% of the remaining information for him is incomplete. The source also noted that data for Rose are incomplete for 1971, 1972, and 1973. No such qualifier pertains to the data for Murray.

RESULTS

The generalized matching equation (Equation 1) was used to analyze all data, with B1 consistently representing left-handed (L) at bats, B2 representing right-handed (R) at bats, and R1 and R2 representing the respective consequences of those at bats (TB, RBI, HR).

Figures 1, 2, and 3 show the logarithms of the ratios of left- to right-handed at bats graphed as a function of the logarithms of the ratios of TB, RBI, and HR, respectively, resulting from such at bats. Each data point represents data from one year for the indicated player and so, for example, for TB there are 17, 21 and 24 data points for Mantle, Murray and Rose, respectively. In Figure 3 (HR) there is one fewer data point for Murray and there are nine fewer for Rose than in the other two figures, as HR was zero for either L or R at bats for some years. The solid lines were fitted to the data using the method of least squares. The equations describing these lines are shown on the graphs and the coefficients (a and $\log c$), the standard deviations of these coefficients (SD_a and $SD_{\log c}$), the correlation coefficients (r) for each relation, the t -values (for testing if the slopes are statistically significantly different from zero), and the degrees of freedom (df) for these t -tests are given in Table 1. The degree of bias is the y-intercept of the regression line or $\log c$ (e.g., 0.148 for Mantle's TB). The slope of the regression line is a (e.g., 0.240 for Mantle's TB). Because logarithmic transforms were used, an a of 1.0 and a $\log c$ of 0 would represent strict matching, and the diagonal dashed lines on the graphs indicate where the data would fall were there strict matching between the logs of the at-bats ratios and the logs of the TB, RBI and HR ratios. A relation with a slope less than 1.0 would be described as showing undermatching, and one with a slope greater than 1.0 would be described as showing overmatching.

Table 1 shows that for the TB data in Figure 1 all three correlations are significantly different from 0 for TB with Rose's TB data having the largest correlation with at bats. The t -test results shown in Table 1 indicate that all three slopes are significantly greater than 0. The standard deviations of the slope and intercept estimates (SD_a and $SD_{\log c}$) can be used to calculate the ranges within which the true parameter value is expected to fall with 95% confidence [i.e., the 95% confidence interval (CI)]. All three slopes are less than 1.0 and all three 95% CIs ($a \pm 1.96 SD_a$) do not include 1.0. With respect to TB, bias for batting left-handed (positive $\log c$) is apparent for Mantle and Murray and bias for batting right-handed is apparent for Rose. However, the 95% CIs around the intercepts ($\log c \pm 1.96 SD_{\log c}$)

Table 1

The slopes (a) and intercepts ($\log c$) of the fitted lines, the standard deviations of these parameter estimates (SD_a and $SD_{\log c}$), the obtained t values (to test for the slope being different from 0), the obtained r values, and the degree of freedom (df) for each relation.

Player		a	SD_a	t	df	$\log c$	$SD_{\log c}$	r
Mantle	TB	0.240 ^y	0.055	4.355*	15	0.148 ^y	0.053	.815*
	RBI	0.196 ^y	0.061	3.225*	15	0.151 ^y	0.047	.641*
	HR	0.240 ^y	0.135	1.774*	15	0.207 ^y	0.037	.583*
Murray	TB	0.300 ^y	0.037	8.125*	19	0.069	0.053	.743*
	RBI	0.250 ^y	0.033	7.604*	19	0.105 ^y	0.040	.791*
	HR	0.226 ^y	0.099	2.284*	18	0.226 ^y	0.062	.361
Rose	TB	0.458 ^y	0.036	12.803*	22	-0.070	0.054	.917*
	RBI	0.050 ^y	0.079	0.637	22	0.408 ^y	0.077	.224
	HR	0.043 ^y	0.114	0.374	11	0.329 ^y	0.047	.148

* slope significantly > 0 and $\pi > 0$, $\alpha < .05$

^y slopes where 95% CI does not include 1.0 and intercepts where 95% CI does not include 0.

include zero for Murray (from -0.035 to 0.173) and for Rose (from -0.175 to 0.036) but not for Mantle (from 0.088 to 0.208). Thus, only Mantle's at bats show a reliable degree of left-handed bias in relation to TB.

Mantle's and Murray's RBI data as depicted in Figure 2 have significant correlations and have slopes that are significantly greater than 0 (Table 1), while the line describing Rose's RBI data is flat (i.e., the slope is not significantly different from 0) and these data do not have a significant correlation. None of the three slopes include 1.0 within a 95% CI, thus they show undermatching. All three functions have positive $\log c$ values and none of these intercepts include 0 within a 95% CI, thus all three also show left-handed biases. Table 1

indicates that the HR data in Figure 3 follow the same pattern as the RBI data, with slopes significantly greater than 0 for Mantle and Murray but not Rose, but all slopes are less than 1.0, and all three functions show left-handed biases.

Overall, Rose's TB data show the greatest degree of sensitivity as they have the largest correlation and associated slope but his RBI and HR data are both basically flat and have the smallest correlations and associated slopes of all the data sets. All slopes except these two are significantly greater than 0 and all slopes are different from 1.0. Thus, for all hitters and outcome measures, there was undermatching in every case. That is, the relative number of left-handed at bats was less than the number

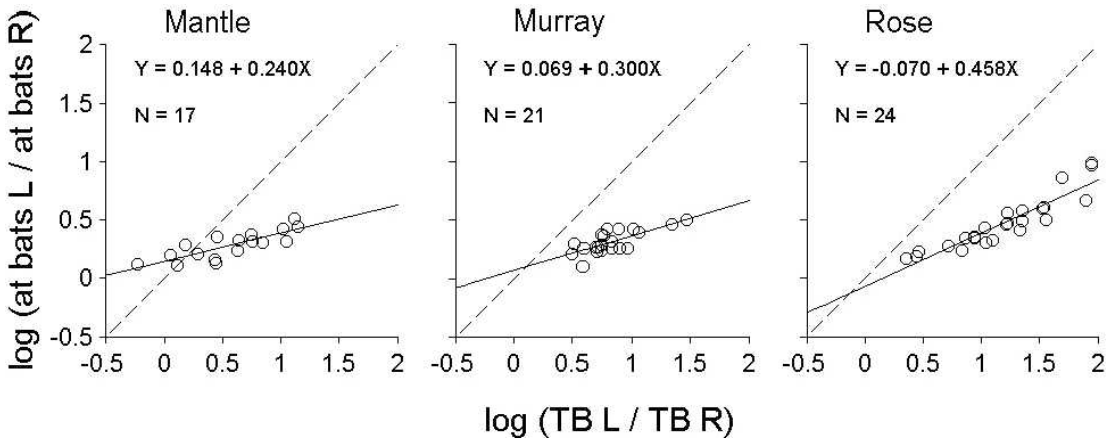


Fig. 1. The logarithm of the ratios of left- (L) to right-handed (R) at bats as a function of the logarithms of the ratios of total left (TB L) and right (TB R) bases produced by those at bats. Details are provided in text.

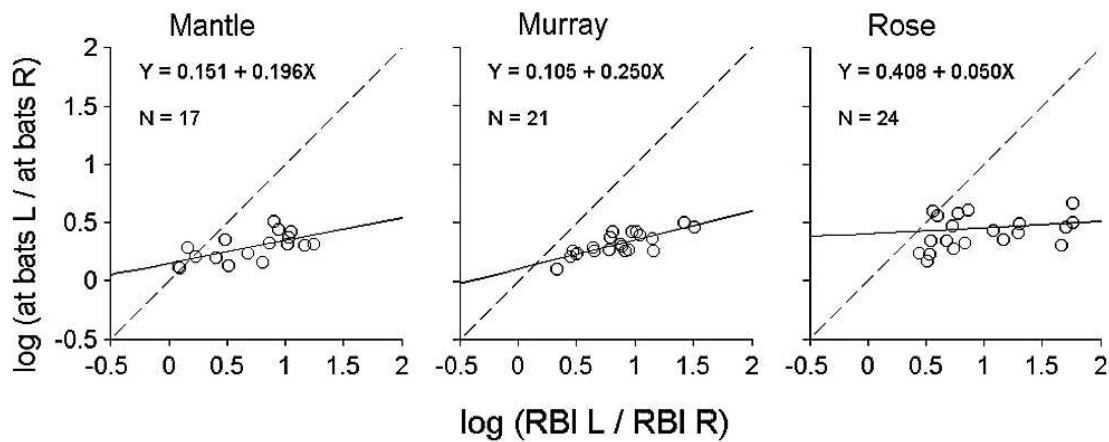


Fig. 2. The logarithm of the ratios of left- (L) to right-handed (R) at bats as a function of the logarithms of the ratios of left (RBI L) to right (RBI R) runs batted in produced by those at bats. Details are provided in text.

that would have been found had the at bats matched the outcomes. Bias for batting left-handed (i.e., positive $\log c$) was apparent in eight of the nine cases, with the data from TB for Rose the exception. The smallest $\log c$ values are with TB for all batsmen. For Mantle and Murray, bias for batting left-handed is largest for HR and for Rose it is largest with RBI. All but the two smallest biases can be said to be nonzero, and these positive nonzero biases indicate a disproportionate number of left-handed at bats regardless of the outcome of such at bats.

DISCUSSION

Many previous studies showed that the generalized matching equation provides a good description of the relation between behavioral outputs, defined in terms of responses or time allocated to obtaining alternative sources of reinforcement, and environmental inputs, defined as frequency or some other dimension of reinforcement earned for those alternatives (e.g., Davison & McCarthy, 1988; McDowell, 2005). This occurs not only in controlled laboratory investigations, but in

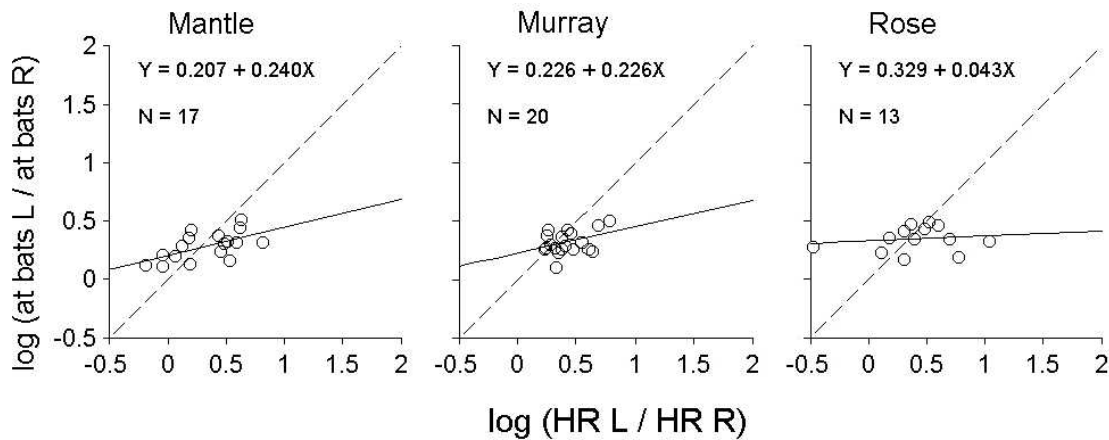


Fig. 3. The logarithm of the ratios of left- (L) to right-handed (R) at bats as a function of the logarithms of the ratios of left (HR L) to right (HR R) home runs produced by those at bats. Details are provided in text.

Table 2
Summary Statistics for All 2009 Major League Baseball Players[#].

Hitter	Pitcher	HR/100 AB	RBI/100 AB	TB/100 AB	BA*
Right-handed	Right-handed	3.02	13.26	40.69	.257
Right-handed	Left-handed	3.52	12.46	43.06	.268
Left-handed	Left-handed	2.76	12.93	38.58	.247
Left-handed	Right-handed	3.03	12.69	42.99	.269

[#] data were obtained from Baseball-Reference.Com (2010)

* batting average, the relative number of at-bats that produced a base hit, expressed as the decimal equivalent

everyday life as well. For example, the matching equation provides a fairly good description of two- and three-point shot allocation in basketball (Alferink et al., 2009; Romanowich et al., 2007; Vollmer & Bourret, 2000) and of running versus passing play selection in football (Reed et al., 2006; Stilling & Critchfield, 2010).

Even though the generalized matching equation often accurately describes a human's responding in choice situations, it does not always do so. This is evident in an early review of human matching conducted by Pierce and Epling (1983), who concluded that the preponderance of experiments with humans did demonstrate matching, but there were published notable exceptions. The present findings appear to constitute another exception, although statistical analyses (correlations and *t*-tests) revealed that at bats by Mantle, Murray, and Rose were in most cases sensitive to the consequences we analyzed as reinforcement, hence the generalized matching could be meaningfully applied to the present data. Had those data been subjected to a more detailed analysis, one that took the context of the game (e.g., runners on base, inning, score, dimensions of the ballpark) into account, even stronger relations may have occurred, as was the case when Reed et al. (2006) analyzed football play allocation as a function of down (first, second, third). The present analysis found that at bats by Mantle, Murray, and Rose demonstrated undermatching and a bias towards hitting left-handed. Undermatching, which is generally construed as evidence of insensitivity to reinforcement, is not unusual in studies of choice responding. This is evident in the findings of Kollins, Newland, and Critchfield (1997), who reviewed 25 studies that investigated the performance of humans under concurrent variable-interval schedules and concluded that responding often was

relatively insensitive to programmed consequences and that "human behavioral allocation among alternatives often deviates from predictions based on rates of experimentally programmed consequences" (p. 208). They discuss how a number of variables, including the stimuli arranged as reinforcers and the motivational variables in effect, can contribute to insensitivity.

With respect to the present findings, it appears that the responses of interest, batting left- and right-handed, were controlled by a rule, not by the consequences that we measured. The rule is "bat right-handed against left-handed pitchers and bat left-handed against right-handed pitchers." It is established baseball lore that hitters have less success against same-handed pitchers and this generally is confirmed by data (Clotfelter, 2008; Hertzfel, 1975). As an example, Table 2 presents data for right- and left-handed hitting major league baseball players in 2009, with data analyzed as a function of the handedness of pitchers and hitters. It shows batting average, the relative number of at bats that produced a base hit, expressed as the decimal equivalent, along with HR, RBI, and TB. For ease of comparison, the last three measures are expressed per 100 at bats, making all values greater than one. With the exception of RBIs, performance of both right- and left-handed hitters as a group was better against opposite-handed pitchers.

Like most people, a substantial majority of major league pitchers are right-handed (Baseball Reference.com, 2010). The bias for batting left-handed evident for Mantle, Murray, and Rose seems to reflect the preponderance of right-handed pitchers that they faced and against whom they followed the rule and batted left-handed. As major-league players, they essentially never batted against same-handed pitchers. According to our data source, in their major league careers both

Mickey Mantle and Eddie Murray batted right-handed against a right-handed pitcher on a single occasion and Pete Rose batted left-handed against a left-handed pitcher three times. All went hitless. The results of these five at-bats, which are the only ones in which the handedness of batters and pitchers were the same, suggest that benefit was derived by these hitters typically reversing handedness. These five at-bats constitute only 0.01% (5 of 33,355) of the total at-bats for which data are available and are too few to support meaningful conclusions. Therefore, it is impossible to ascertain whether these hitters actually benefitted from switch hitting. Given that Mantle and Murray are members of the Major League Baseball Hall of Fame and Rose undoubtedly will be if his suspension for gambling is lifted, they certainly excelled as switch hitters. Given that Mantle (Hall, 2005), Murray (Keunster, 1986), and Rose (Jordan, 2004) all were "natural" right-handed hitters, that is, they batted that way when young, it is tempting to speculate that perhaps they should not have changed. On the other hand, batting left-handed has clear advantages (Hertzel, 1975), including starting a step closer to first base and in most cases facing right-handed pitchers, whose curve balls break towards, not away from, the hitter. All three did well from the left side, and perhaps would have had even better careers had they stayed there for all at bats. No one will ever know.

It is perhaps unsurprising that the generalized matching equation did not provide a good description of the present data. The conditions under which baseball players bat do not closely approximate free-operant schedules of reinforcement, such as the variable-interval schedules under which matching is particularly robust (Davison & McCarthy, 1988). Each pitch constitutes an isolated opportunity to swing and to produce one of the outcomes that we measured, thus the arrangement more closely resembles a discrete-trial procedure than a free-operant one. Response (or time) allocation under discrete-trial procedures is often relatively insensitive to reinforcement parameters and hence is not well described by the generalized matching equation (e.g., Hall-Johnson & Poling, 1984). Play selection in football, however, also does not closely resemble a conventional free-operant reinforcement schedule, and the equation did provide a reasonable description

of the relation between the relative number of pass and run plays selected and the relative number of yards yielded by such plays (Reed et al., 2006; Stilling & Critchfield, 2010).

Historical accounts of the early baseball experiences of Mantle (Hall, 2005), Murray (Keunster, 1986), and Rose (Jordan, 2004) indicate that at a young age each of them was specifically instructed to bat from the side of the plate opposite the pitcher's throwing hand, which is consistent with the suggestion that their choice to bat left- or right-handed as major league players was rule-governed, not contingency-shaped. But even if their choices were primarily rule-governed, as we suggest, strict matching could have obtained between the environmental inputs and behavioral outputs that we analyzed. This possibility provided the primary rationale for the present study. The findings of that study are significant in representing a counter-instance of demonstrations of a matching relationship in sports in particular and in human behavior in general and in calling attention to the need for further study of the variables that affect choice.

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